International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249–6890; ISSN(E): 2249–8001
Vol. 9, Issue 6, Dec 2019, 585–594

INVESTIGATION OF A NEW WEDGE DISC BRAKE MECHANISM

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ABSTRACT

Most cars' front brakes are of the disc type, but the rear brakes are of the drum type. Older cars often had drum brakes on all four wheels, and many new cars now have four-wheel disc brakes. The aim of this research is to investigate the ability of manufacturing and testing a new mechanism for wedge disc brake. The new mechanism consists mainly of the wedge itself, which is controlled by a gear set to change its inclination angle. The wedge is sliding on a surface controlling its inclination angle. The control of the inclination angle can change the factor between the applied force from the brake pressure source and the normal force to the brake pads. Changing the normal force to the brake pads can change the brake force on the rotor disc. The brake force from the pads on the rotor disc is the main goal in this research. The goal is to increase this force by increasing the normal force on the brake pads. The new mechanism was manufactured and tested experimentally in the laboratory by the use of a lathe machine carrying the mechanism for investigation. The results showed the ability of the new mechanism to increase the brake force by about seven times than conventional disc brake. The tested inclination angles were 45^o, 35^o, 25^o, 15^o, 12^o and 10^o with different rotational speeds of 76, 150, 230 and 305 rpm at different applied hydraulic pressures of 5, 7.5, 10 and 12.5 bar. In all the above-mentioned cases, the inclination angle of 12^o was found to be the best angle in increasing the brake force.

KEYWORDS: Wedge Disc Brake, Applied Force, Wedge Inclination Angle & Brake Force

Received: Aug 27, 2019; **Accepted:** Sep 17, 2019; **Published:** Nov 11, 2019; **Paper Id.:** IJMPERDDEC201950

Original Article

INTRODUCTION

Brakes can be described as a tool to slow or stop the turning motion of the vehicle wheels through transforming kinetic energy to heat (Giri 2007). The drum and disc brakes are the two main types of friction brake. Disc brakes have many advantages than drum brake of that fade resistance, self-adjustment and freedom of pull. Therefore, drum brake systems for vehicles are being replaced with disc brake systems. It should be noted that the main disadvantage of disc brake system is non-occurrence of the self-energizing phenomenon (Halderman 2009). Hence, so there were many efforts to modify the disc brake system that could be self-amplified. In wedge disc brake system, a great brake force can be achieved with a small applied force. There were many models of wedge disc brake systems according to applied force direction whether it is normal or tangential. It has different advantages such as improved ABS performance, especially on slippery roads, continuous brake power distribution, shorter stopping distance and environmentally friendly brake system (Halderman 2009). Therefore, new wedge disc brake will be investigated in this study. Coefficient of friction μ, which is between pads and rotor disc presented by Coulombads an is defined as the ratio of brake force to the applied force. Many efforts were done to determine it accurately, for example, Blau (1995), and Serverin and Dörsch (2001), presented a friction law based on many

parameters such as normal force, sliding speed, contact temperature and number of brakes. However, it has no exact trend with these working parameters. The ratio of the total brake force to the applied force is called as the characteristic brake factor C*, which is considered as the main performance of the vehicle braking system (Leber, 1998). It depends basically on the value of friction coefficient. Serverin and Dörsch (2001) have presented the variation in the characteristic brake factor C* with different friction coefficients. They found that the characteristic brake factor is affected by friction coefficient μ variations with uneven impact, where the degree of influence of the friction coefficient μ on the characteristic brake factor C* is higher with the self-amplified brakes (drum and wedge) than with the conventional disc brakes. Wedge disc brake, which is its mechanical model shown in Figure 1, is an application of mechatronics in a new disc brake system. The concept of Roberts *et al*. (2003) was based upon the application of self-amplification action in the disc brake system by using a wedge mechanism. This mechanism is similar to the patent presented by Dietrich *et al*. (2001). In this work, the researcher tries to find the optimal operating point. The characteristic brake factor C* is:

$$C^* = \frac{2\mu}{\tan(\alpha) - \mu}$$

where α is a wedge inclination angle. They even considered using the operating point when the characteristic brake factor C* is infinity, i.e., the term tan(α) – μ becomes zero.

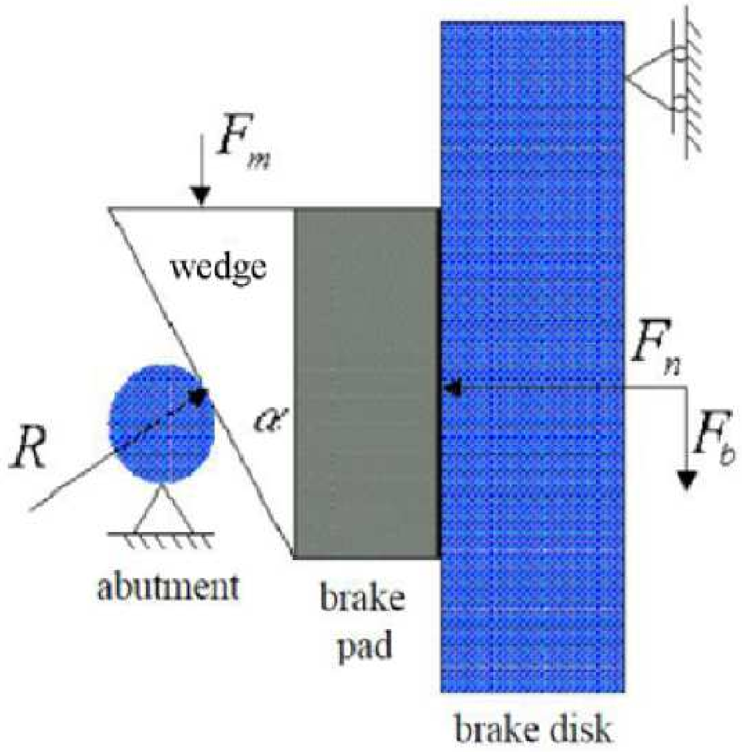


Figure 1: Mechanical Model of Wedge Disc Brake by Hartmann (2001).

NEW TECHNIQUE DESCRIPTION

The test rig was built in order to generate the kinetic energy required for the system and then brake this energy by the brake wedge mechanism and measure the brake force at different speeds, applied forces and different wedge inclination angles. The test rig consists of driving mechanism, flexible coupling, brake rotor disc, brake wedge mechanism, hydraulic connections for the brake fluid and a measuring system for the brake force. The test rig is shown in Figure 2.

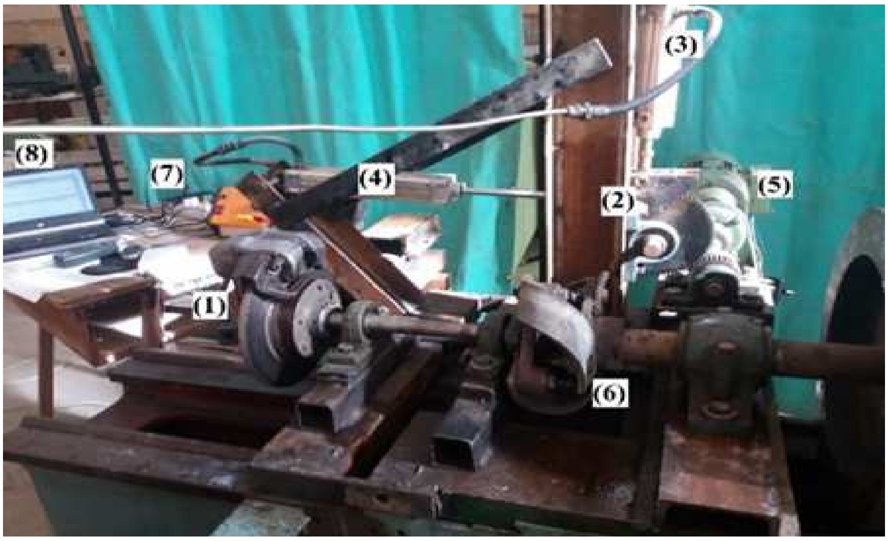
The driving mechanism is mainly the gearbox of the lathe machine to give the system the ability of working with different speeds. The driving mechanism is also having a flywheel to give the required inertia force for the braking system. The lathe itself is driven by an AC electric motor characterized by a constant rotational speed with maximum power of 10 hp (7.46 kW) at 1450 rpm.

The brake rotor disc is the element for testing the brake force on it and it has brake pads installed on it and connected with the brake wedge mechanism by the hydraulic connections.

The new wedge mechanism is shown in Figure 3. The wedge mechanism is the most important part in the system, which consists of two metallic parts, which have an inclined sliding surface between them and has an inclination of 45^{o}, the lower part is connected to a gear driving mechanism to control the inclination of this part, the upper part is the wedge, which is connected to the hydraulic connections from the applied force source and to the normal force on the brake pads, which is installed on the rotor disc. The lower gear controlling the inclination angle of the wedge mechanism is driven by an electric motor with brake to adjust the inclination of the lower part of the mechanism, as shown in Figure 3. The sliding surface between the two parts of the wedge has a ladder bearing to prevent the friction between these two parts.

The hydraulic connection is the main part transferring the pressure from the hydraulic pedal to the brake pads. These connections take the pressure from the hydraulic pedal by means of a hydraulic press, this pressure is transferred to the wedge by another hydraulic press numbered 3 in Figure 2. After the wedge, there are other hydraulic connections transferring the pressure from the wedge to the brake pads, as shown in Figure 3.

After conducting the test and applying the brake force on the rotor disc, a measuring system for the disc braking force is installed to measure and record the brake force.



1: Rotor Disc, 2: New Wedge Disc Brake, 3: Hydraulic Press (A); 4: Hydraulic Press (B); 5: Inclination Angle Control; 6: Coupling; 7: Measuring System; 8: Computer.
Figure 2: Experimental Test Rig.

The applied force from the hydraulic pedal to the hydraulic press (a) at Figure 2 can be adjusted by using a pressure gauge with a control valve. The applied force acting from the hydraulic press (a) to the wedge moving it to force the hydraulic press (b) which generates the normal force at the hydraulic connection from press (b) to the brake pads. The normal force from the wedge is measured by a hydraulic gauge and recorded during the test.

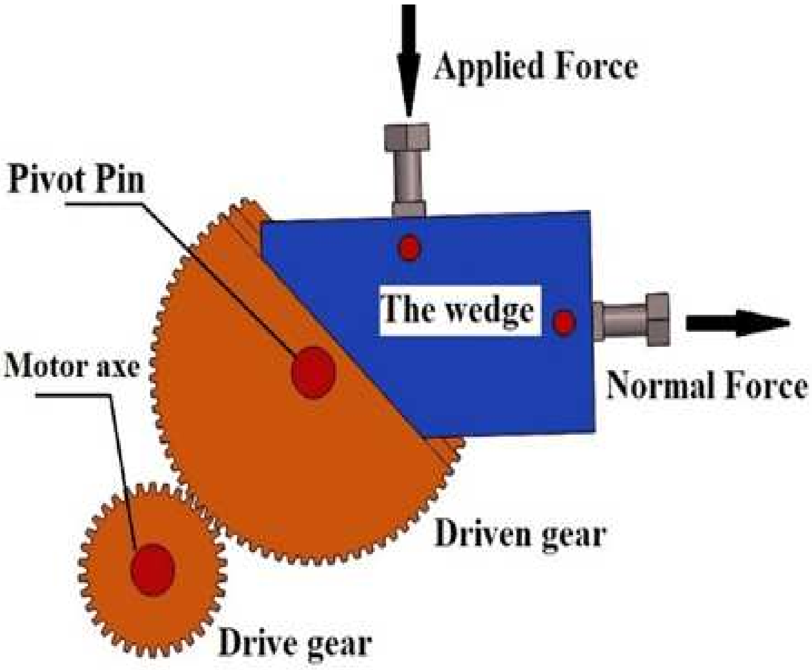


Figure 3: New Wedge Mechanism.

MEASUREMENT INSTRUMENTATION

The designed test rig with the measurement instrumentation is shown schematically in Figure 4. The instrumentation includes

- Applied force measurement.
- Rotational speed measurement.
- Brake force measurement.
- Friction temperature measurement.

The applied force can be measured by a pressure gauge installed in the hydraulic line after the pedal. The hydraulic pressure of the brake fluid in the line can be multiplied by the area of the press (a) to obtain the applied force. The hydraulic press (a) and (b) pistons have a diameter of 40 mm. The applied force is adjusted to the required value by using a control valve.

The rotational speed of the lathe machine is adjusted to the required rpm and was also checked by the use of a digital photo tachometer.

The brake force is measured by a load cell (tension–compression load cell with 400 kg maximum load), which was installed beside the rotor disc and the force transmitted to it by means of a metallic connection was tightened to the rotor disc.

The temperature due to the friction was measured by a thermocouple mounted on the rotor disc above the brake pads.

The brake force and the temperature of the friction were recorded using a data logger transferring these readings to the computer to record it, as shown in Figure 4.

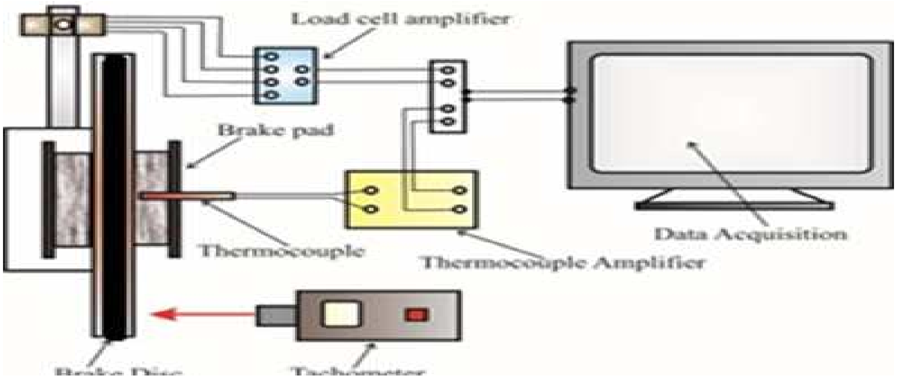


Figure 4: Schematic Sketch of Brake Force, Temperature and Speed Measurement Instrumentations.

EXPERIMENTAL WORK

The experiments were conducted to check the new wedge mechanism effect and to decide the optimum inclination angle for the wedge.

The selected parameters for the experiments were as follows:

The rotational speed (N) of 76, 150, 230 and 305 rpm.

The applied pressure (Papp) of 5, 7.5, 10 and 12.5 bar these values of pressure equals applied forces (Fapp) of 628.572, 942.857, 1257.143 and 1571.43 N, respectively.

Inclination angle (α) of 45, 35, 25, 15, 12 and 10 degrees.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Influence of Wedge Inclination Angle

The effect of the wedge inclination angle on the brake force is shown in Figure (5). The decrease of the inclination angle from 45° to 12° increases the value of the brake force from 4788 N to 8400. N at Papp of 12.5 bar nearly 1.8 times. The results explain the increasing of the self-energizing action of the wedge brake with the decreasing of the wedge angle. Increasing the self-energizing action increases the normal force causing increasing the brake force. This is in agreement with Roberts (2003) and Hartman (2001),but less than 12greement with Roberts (2003) and Hartman (2001)force caue behavior due to the resistance of hydraulic press links (number 3 and 4 in Figure 2) to the motion of the wedge.

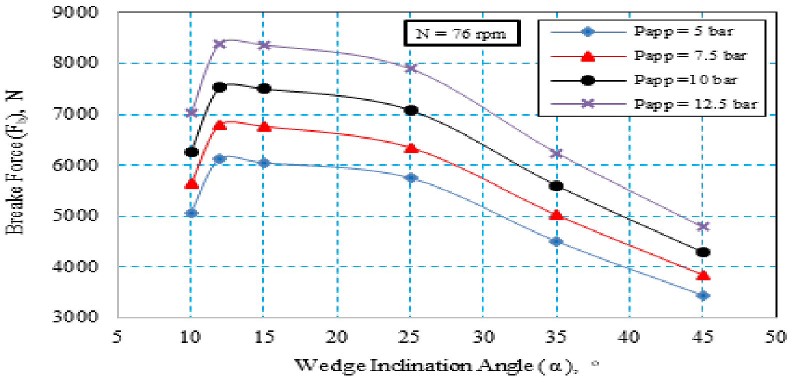


Figure 5: Effect of Wedge Inclination Angle on the Brake Force at Various Applied Pressures and Constant Rotational Speed of 76 rpm.

Figure 6 shows that the brake force fluctuates with no identical trend with the braking time. The variations of the brake force trend are a result of the friction coefficient trend fluctuations.

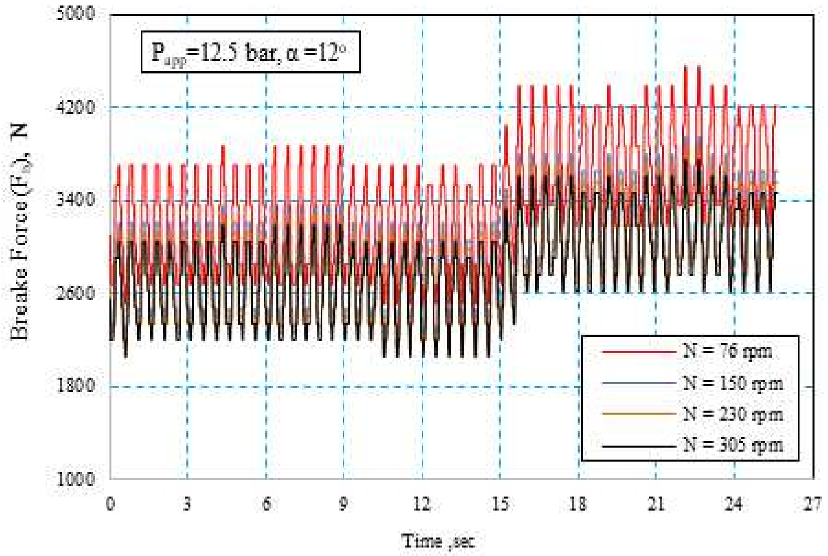


Figure 6: Variation of Brake Force with Time at Various Rotational Speeds and Constant Applied Pressure of 12.5 bar with Inclination Angle of 12º.

Influence of Applied Force

The effect of applied force on the brake force, coefficient of friction μ and characteristic brake factor C* are shown in Figures 7, 8 and 9, respectively. From the results shown, it can be seen that the increase of the applied force causes a great increase of the brake force at all rotational speeds. The effect of the applied force obtained from the relation Fb = normal * μ when accruing an increase in the applied force, there is a decrease in the friction coefficient and hence the characteristic brake factor C* also decreases, this is due to the increase in friction temperature between brake pads and rotor disc.

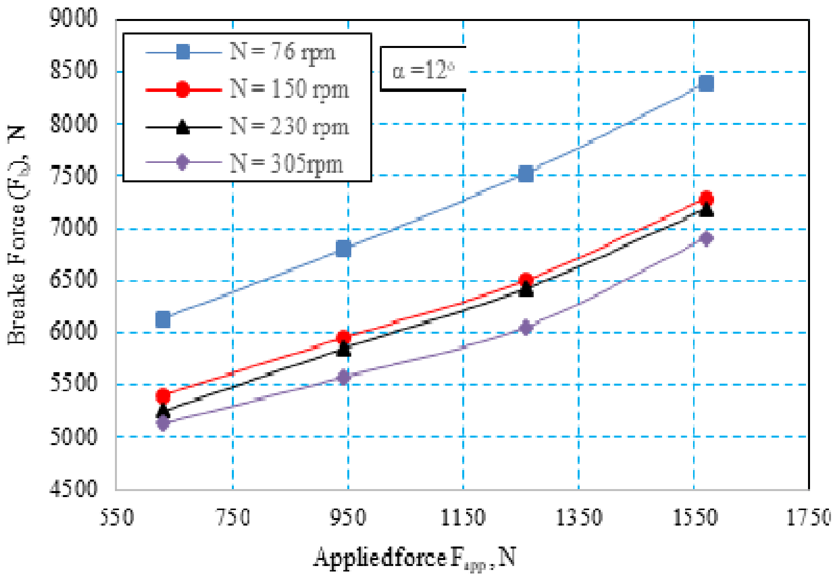


Figure 7: Effect of Applied Force on the Brake Force at Various Rotational Speeds and Constant Wedge Inclination Angle of 12º.

Influence of Rotational Speed

From the results, it can be seen that the increase of the rotational speed causes a decrease of the brake force. Increasing the braking time leads to decreasing the brake force, especially at high speed. This is because of the increase of the friction temperature, which decreases the friction coefficient; therefore, the brake force tends to decrease.

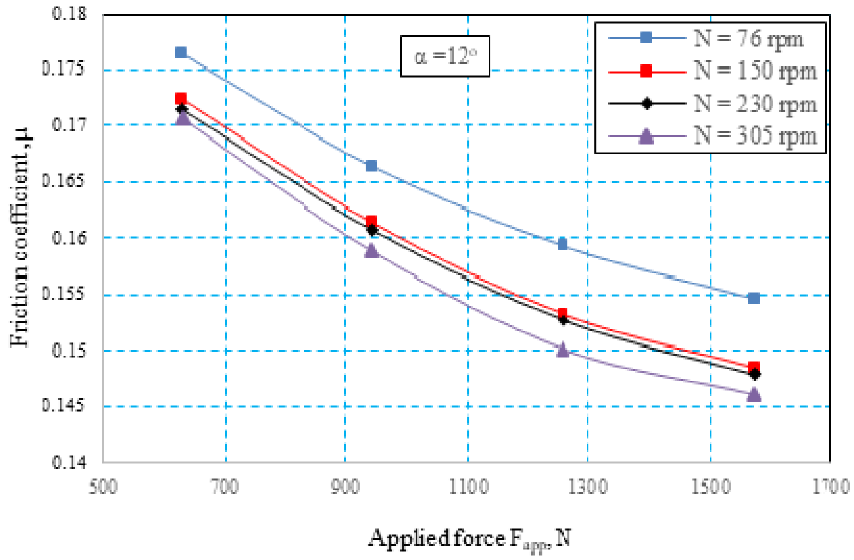


Figure 8: Effect of Applied Force on Coefficient of Friction at Various Rotational Speeds and Constant Wedge Inclination Angle of 12º

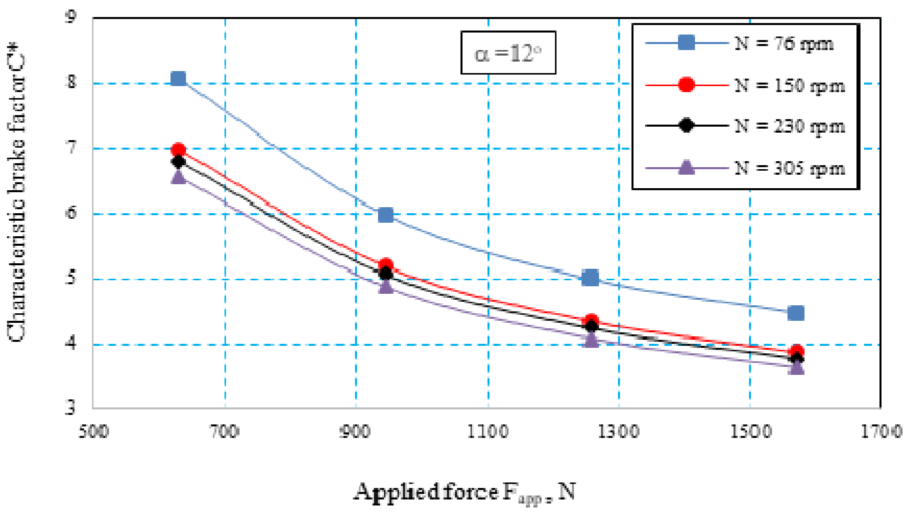


Figure 9: Effect of Applied Force on Characteristic Brake Factor at Various Rotational Speeds and Constant Wedge Inclination Angle of 12º.

CONCLUSIONS

From the experimental work, the following conclusions can be obtained:

- The increase of the applied force increases the brake force of the new wedge disc brake. The wedge inclination angle has a significant effect on the new wedge disc brake performances. The self-energizing action of wedge disc brake increases with the decrease in wedge inclination angle.

- The higher the applied force, the lesser the coefficient of friction and characteristic brake factor for wedge disc brakes.
- The brake force decreases with the increase of rotational speed due to the increasing of friction temperature.

ACKNOWLEDGEMENTS

The authors would like to thank Beni-Suef University and Industrial Education College for helping and supporting.

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